RP76

RELATION OF RADIO WAVE PROPAGATION TO DISTURBANCES IN TERRESTRIAL MAGNETISM

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ABSTRACT

This paper presents the results of a study of an apparent interrelationship between radio reception and changes in the earth's magnetism. The results show that for long-wave daylight reception over great distances (4,000 to 7,100 km) there is, in general, a variable but definite increase in the intensity of the received signal following the height of severe magnetic disturbance. This increase reaches its maximum in from one to two days and disappears in from four to five days. For moderate distances (250 to 459 km) there is an increase in the intensity of the received signal noticeable before as well as after the magnetic storm reaches a maximum. These changes in intensity cover periods from two to four days both before and after the magnetic storm reaches its height.

In a paper presented before the Institute of Radio Engineers in May, 1925, Espenschied, Anderson, and Bailey [1] pointed out that at times of severe magnetic storms abnormal radio transmission was likely to occur, night field intensities being greatly reduced and daylight intensities slightly increased. These conclusions were based upon hourly observations (for one day a week) of low-frequency transmission (57 kc) across the Atlantic covering a period of about two years. From a more exhaustive analysis of this same material, with the addition of later observations, Anderson [2] in 1928 concludes:

> High daylight radio field strengths (at 57 kc) obtain during periods of marked magnetic activity. In most cases the magnetic disturbances precede the high values, but there is evidence of an abrupt rise to high values preceding the magnetic disturbance and at times a gradual rise to high values independent of the magnetic activity. * * * It is seen that the high radio fields do not occur particularly on days of high magnetic character but rather during periods when magnetic storms occur. Because the radio data are available for one day a week only, no detailed conclusions can be drawn. For the most part, however, the high fields follow the magnetic disturbance and then gradually fall off.

Pickard,[3] from a series of observations on broadcast reception taken at Newton Center, Mass., on the Chicago station WBBM (800 to 900 kc), concludes that the "depression of night reception accompanying magnetic storms is very striking. Day reception from Nauen, AGS (24 kc), shows an inverse effect, and increase of field accompanying and following the storm."

[1] Espenschied, Anderson, and Bailey, Bell Tech. J., **13**, No. 3; 1925; Proc. I. R. E., **14**, p. 7; 1926.
[2] C. N. Anderson, Proc. I. R. E., **16**, No. 3, p. 297; 1928.
[3] G. W. Pickard, Proc. I. R. E., **15**, No. 2, p. 83; 1927; No. 9, p. 749; 1927; No. 12, p. 1004; 1927.

In a paper [4] presented before a meeting of the International Union of Scientific Radio Telegraphy in Washington, October, 1927, it was pointed out that the field intensity of the American station WSS (18.5 kc) for the duration of eight months when averaged in periods of five days, exhibited a marked tendency to vary with the diurnal range of horizontal intensity of the earth's magnetic field. This indicated the possibility of a day by day relationship between magnetic disturbances and variations in signal strength. The present study was, therefore, undertaken to determine whether such a correlation existed. A long series of reception data consisting of daily observations on low-frequency stations (15 to 23.4 kc) was available, which was particularly suitable for this investigation. These measurements had been made at the Bureau of Standards by the telephone-current comparator method.[5] Field intensity measurements from two groups of stations were examined—those made on signals from long distances (4,000 to 7,100 km) and those on signals from moderate distances (less than 500 km). For the former observations taken from 10 to 11 a. m. on Lafayette (LY), Ste. Assise (FU and FT), Nauen (AGS and AGW), Rugby (GBR), Coltano (ICC), and Bolinas (KET) were utilized, and for the latter observations at 10 a. m. and 3 p. m. on the Radio Corporation stations at Tuckerton, N. J. (WGG); New Brunswick, N. J. (WRT and WII); and Rocky Point, L. I. (WSS). In order to eliminate as much as possible any variations due to conditions not generally effective, stations of approximately the same wave length were grouped and the data were averaged. Thus, in Figure 1, LY (15.9 kc), FU (15.0 kc), AGW (16.5 kc), and GBR (16.1 kc) are grouped together; in Figure 3, AGS (23.4 kc), FT (20.8 kc), Bolinas KET (22.9 kc), and ICC (19.9 kc); and in Figure 4, the Radio Corporation stations WII (21.8 kc), WGG (18.9 kc), WRT (22.7 kc), and WSS (18.7 kc).

The field intensity of low-frequency signals is believed to be less influenced by magnetic storms than that of the broadcast range. For this reason only the most severe disturbances were considered in the calculations. Since practically all severe magnetic storms occur simultaneously over the earth, the observations taken at the Cheltenham Magnetic Observatory, of the United States Coast and Geodetic Survey, were considered sufficiently indicative of changes in magnetic activity. As a qualitative measure of daily magnetic activity, "magnetic character of day" numbers [6] were used to determine the occurrence of and to locate the central day of the magnetic storms which were selected in preparing the data in Figures 1, 3, and 4, and the

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[4] L. W. Austin and I. J. Wymore, Proc. I. R. E., **16**, No. 2, p. 166; 1928.

[5] L. W. Austin and E. B. Judson, Proc. I. R. E., **12**, p. 521; 1924.

[6] For a qualitative estimate of magnetic conditions days are commonly divided into three classes and designated as follows: 0 denotes days which are magnetically quiet; 1, moderately disturbed days; and 2, severely disturbed days.

diurnal range of horizontal intensity of the earth's magnetic field was used for comparison in Figures 5 and 6.

Days for which the magnetic character number was reported as 2 at Cheltenham, Md., were considered days of maximum magnetic activity and are represented by the zero point of the abscissae in Figures 1, 3, and 4; that is, they are the central days of 11-day periods extending from five days before to five days after each magnetic storm. Averages were made of the radio field intensity of the stations on the corresponding days of these 11-day periods

The following table gives the dates of the magnetic storms considered in the calculations:

1925	1926	1927
Jan. 19–20.	Jan. 26–27.	Mar. 28.
May 4.	Feb. 23–24.	Apr. 14.
June 13.	Mar. 5.	May 5.
June 24.	Apr. 14–16.	July 21–22.
July 26.	May 4–5.	Aug. 20–21.
Aug. 22–23.	June 1–2.	Oct. 10.
Sept. 1–2.	Sept. 9.	Oct. 12.
Sept. 14–15.	Sept. 15.	Oct. 22–23.
Sept. 21.	Sept. 20–21.	
Oct. 23–24.	Oct. 14–16.	
Nov. 9.		

In Figure 1 are given the daylight values of the percentage deviations from the corresponding monthly averages of signal intensity of the long-wave European stations (LY, FU, AGW, and GBR) during the time of greatly increased activity of the sun in the years 1925, 1926, and 1927. While the values for the curves are smoothed, they approximate closely the actual deviations obtained. The trend of the curves before the maximum of the magnetic storms varies somewhat in the three years although, in general, it tends to fall below the average. The most striking similarity is the high value on all the curves on the second day after the peaks of the storms. In connection with this, the behavior of signals at the time of one extremely severe disturbance, that of October 12, 1927, is interesting. In Figure 2 the percentage deviations from the monthly averages of field intensity for the stations, Lafayette (LY), Nauen (AGS), and Bolinas (KET) at the time of this storm are given. Intensities well above average were observed on October 12, the day of the maximum disturbance, but on October 14, two days following, the intensity had increased so greatly that in some cases it was more than 200 per cent above the average value for the month. This increase in signal strength is too great to be a recovery from an abnormal condition before the storm and so probably represents some real effect of the condition productive of the magnetic disturbance.

In order to obtain some idea of the variation of signal strength on magnetically quiet days, an average for each of three years was made

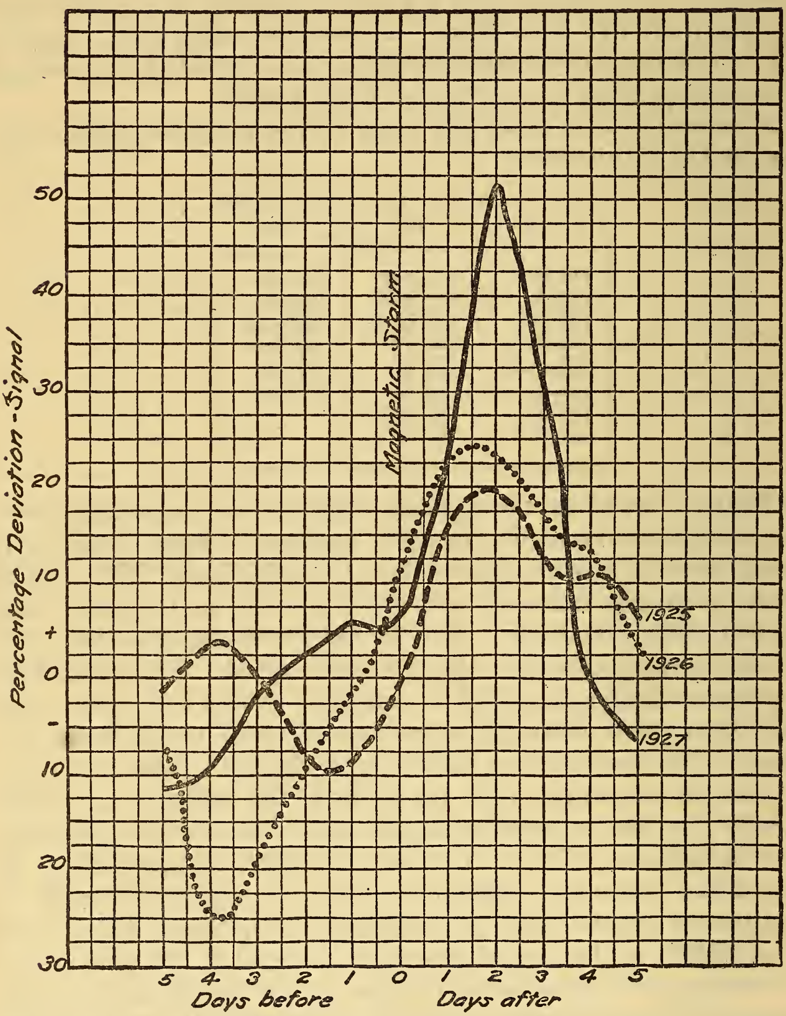

FIGURE 1.—*Average daily deviation from the monthly mean of daylight field strength of signal from stations in Europe (LY, FU, AGW, GBR) during the progress of magnetic storms, 1925, 1926, 1927*

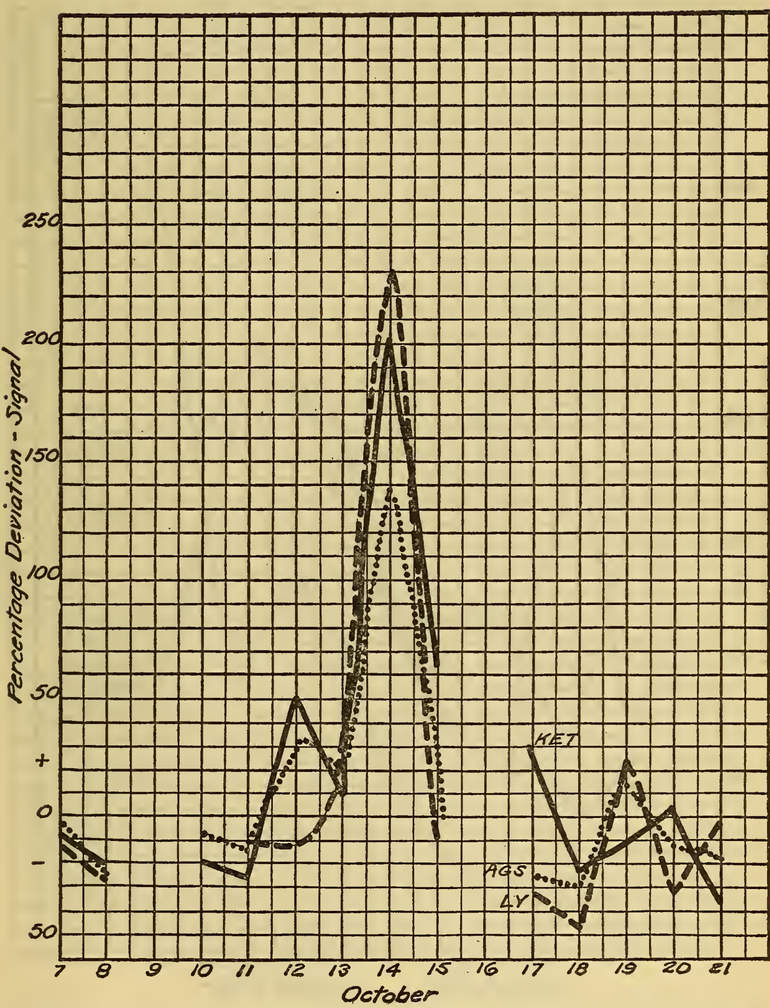

FIGURE 2.—*Deviations in signal strength from the monthly average during the progress of the magnetic storm of October 12, 1927*

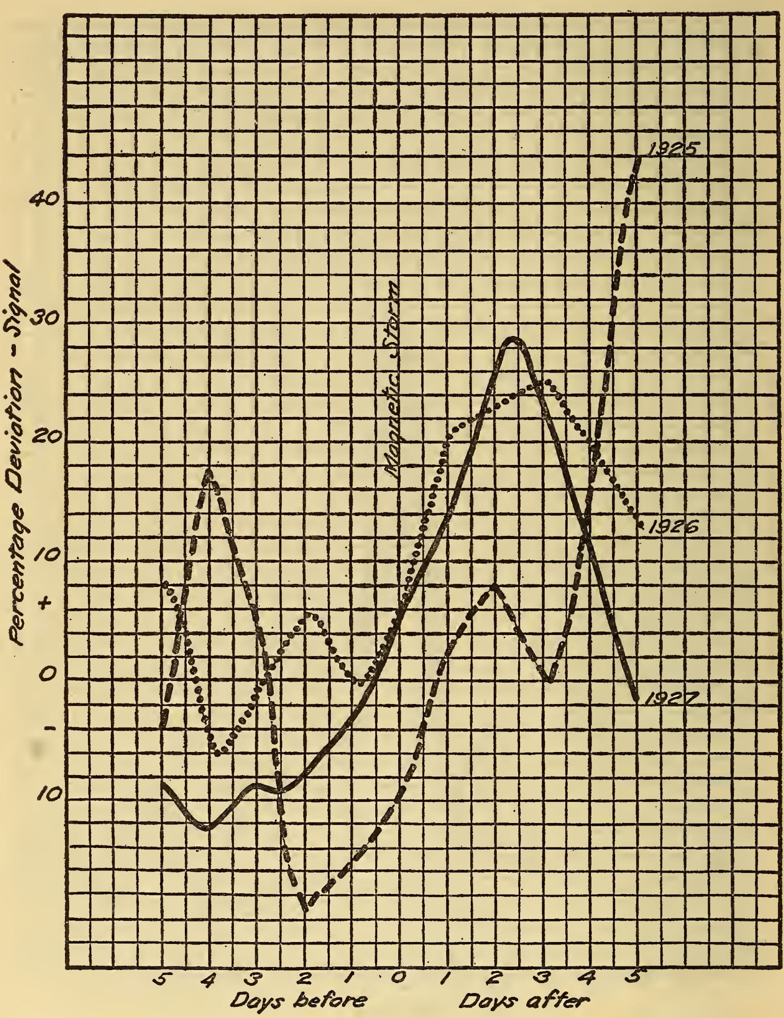

FIGURE 3.—*Average daily deviation from the monthly mean of daylight field strength of signal from stations in Europe and California (FT, AGS, KET, ICC) during the progress of magnetic storms, 1925, 1926, 1927*

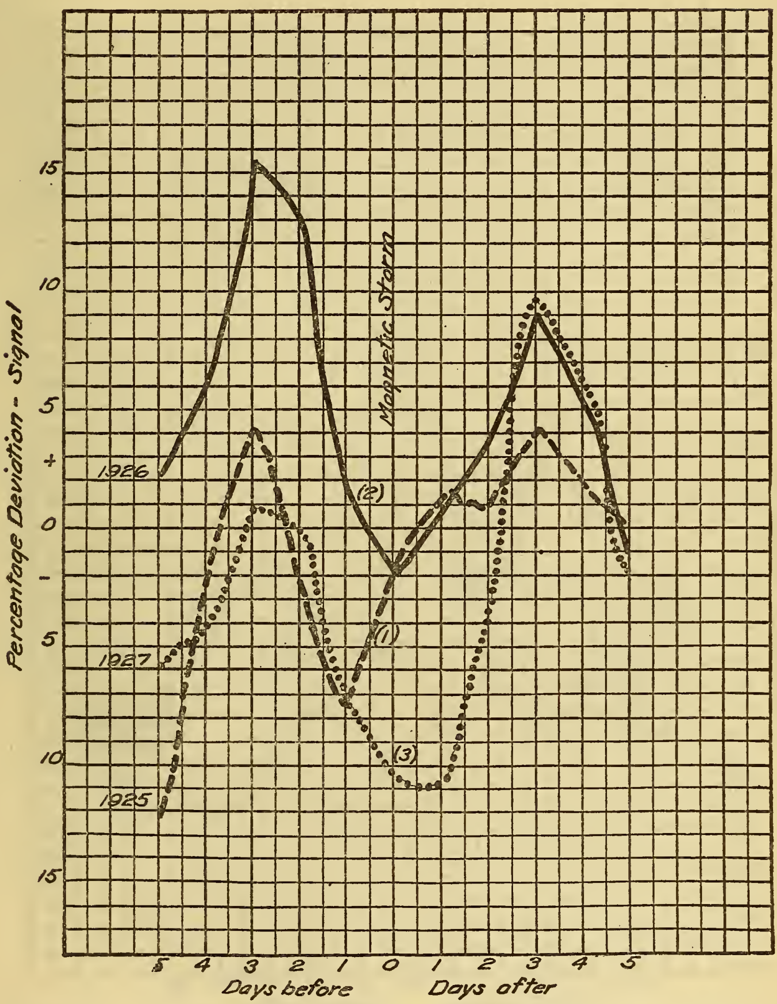

FIGURE 4.—*Average daily deviation from the monthly mean of daylight field strength of signal from stations in New Jersey and Long Island during the progress of magnetic storms, 1927*

(1) WII and WGG, 1925; (2) WII, WGG, and WSS, 1926; (3) WII, WGG, WSS, and WRT

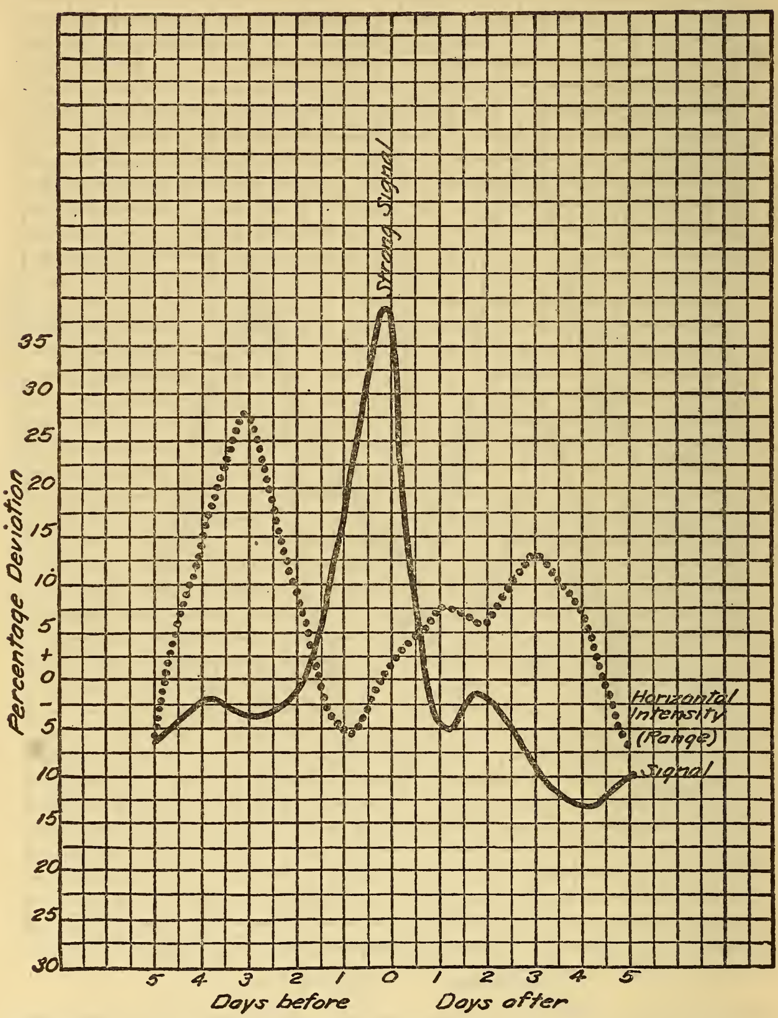

FIGURE 5.—*Average daily deviation from the monthly mean of daylight field strength of signal (Rocky Point, WSS) and of horizontal intensity (range) of the earth's magnetic field, 1926*

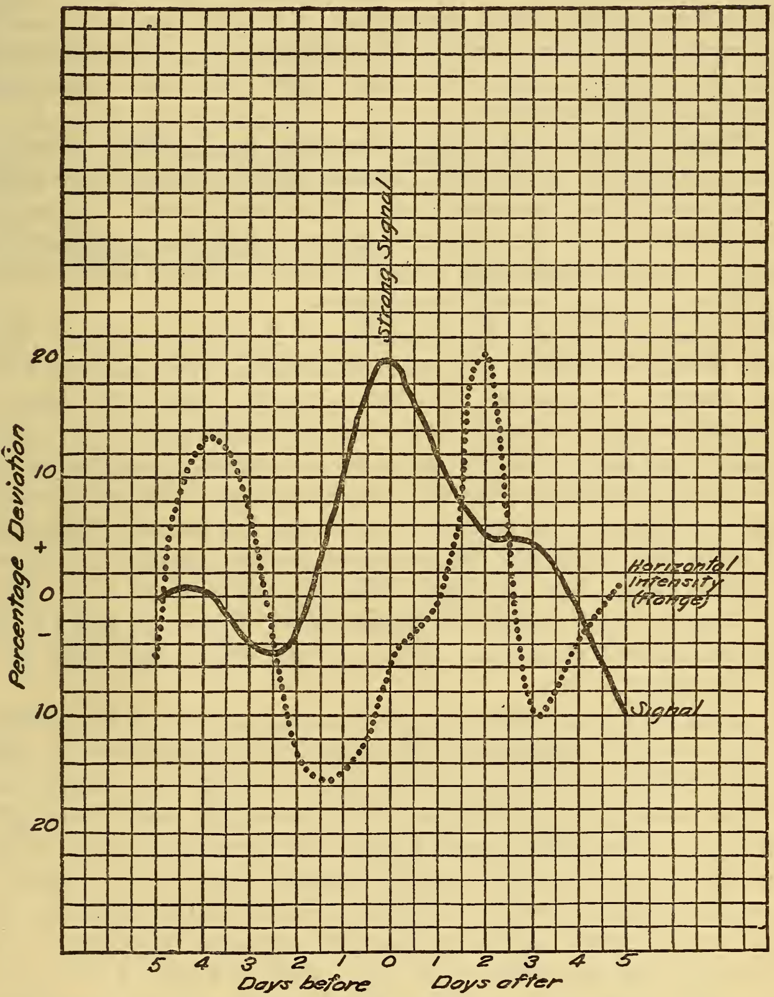

FIGURE 6.—*Average daily deviation from the monthly mean of daylight field strength of signal (New Brunswick, WII) and of horizontal intensity (range) of the earth's magnetic field, January to July, 1927*

for 12 days which were reported as magnetically quiet (magnetic character number = 0) and which were removed by five or more days from any reported disturbance. For 1925 these results gave an average signal deviation from the monthly average of two-tenths of 1 per cent for quiet days; for 1926, six-tenths of 1 per cent; and for 1927 one-tenth of 1 per cent, the mean for the three years being three-tenths of 1 per cent. Such an average, of course, represents merely the normal variations. Individual variations of field intensity on undisturbed days at times are much larger and may occasionally reach or exceed 10 per cent.

In Figure 3 the average deviations from the monthly means for Nauen (AGS), Ste. Assise (FT), Bolinas (KET), and Coltano (ICC) for the same three years are given. The same general tendency is noted in these curves as in those of Figure 1, with the exception that the curve for 1925 shows high values on both the fourth and fifth days after the maximum magnetic disturbance.

The observations of field intensities of American stations (WII, WGG, WRT, and WSS) at moderate distances gave somewhat different results. In general, they show, for the same three years, a depression of signal strength below normal on the day of the storm, preceded three days before the storm by a considerable rise in intensity and followed three days after by another increase. The daily average deviations from the monthly averages during the periods of magnetic storms for 1925, 1926, and 1927 for these stations are shown in Figure 4. Curve *1* gives the average of WII and WGG at 10 a. m. and 3 p. m., 1925; curve *2* of WII, WGG, and WSS, at 10 a. m and 3 p. m., 1926; and curve *3* an average of WII, WGG, WRT, and WSS, at 10 a. m. for 1927.

A signal whose intensity is 25 per cent or more above the average for the month is considered well above normal and due to some unusual conditions effective along its path. In Figure 5 a comparison is made between the variations in field intensities before and after these days of unusually strong signals and the diurnal range of the horizontal intensity of the earth's magnetic field. The center or zero day is taken as the day on which the observed field intensity was 25 per cent or more above the monthly average. In Figure 5 the station observed was WSS, at 10 a. m., 1926; in Figure 6, WII at 10 a. m., 1927. High values of the diurnal range occurred three days before and from two to three days after the signal peak. All data were smoothed by the formula

$$\frac{a+2b+c}{4}$$

From the foregoing curves it is evident that during periods of magnetic storms the behavior of low-frequency (15 to 24 kc) daylight signals tends to be as follows:

1. *Over long distances (4,000 to 7,100 km).*—The intensity of signal falls below normal for several days before the maximum magnetic disturbance, which is followed by a definite increase in strength from one to four days after the storm.

2. *Over moderate distances (250 to 400 km).*—There is an increase in signal strength above the average from two to four days before the disturbance with values below normal during the height of the storm followed by a strong increase in intensity from two to four days after the storm.

This work was done under the direction of Dr. L. W. Austin at the laboratory for special radio transmission research, Bureau of Standards. The observations were made by E. B. Judson at that laboratory.

WASHINGTON, January 12, 1929.